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SYSTEMATIC PROBLEM FORMULATION IN ACTION DESIGN RESEARCH: THE CASE OF SMART CITIES

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Abstract

The research project presented in this paper is being conducted in collaboration with Dublin City Council and Intel Corporation, and is focused on the development of a Smart City maturity model. This paper focuses on the research methodology that is being used for this study, i.e. Action Design Research (Sein et al. 2011). Particularly, we will describe why this recently proposed methodology is suitable for our research, in comparison with Design Science Research (March and Smith, 1995; Hevner et al. 2004) and Action Research (Baburoglu and Ravn, 1992). Furthermore, we will focus on the problem formulation stage to systematically investigate the topic. A systematic literature review based on the 8-steps method proposed in (Okoli et al. 2010) is presented to explore the factors required to evaluate the environmental and socioeconomic sustainability impact of Information and Communication Technology (ICT) solutions at a city level. Furthermore, Grounded Theory principles were adopted to structure the Smart City ecosystem, and identify the areas in which ICT-enabled services have an impact on the city's social, environmental, and economical performances.

Keywords: Action Design Research, Smart Cities, Systematic Literature Review, Grounded Theory.

1 Introduction

Smart Cities has emerged as an important research challenge. Many contributions focus on describing architectures and overall concepts. However, despite the plethora of suggestions, there is a need for a systematic approach to researching this topic and the research described in this paper addresses this opportunity.

The research project presented in this paper is being conducted in collaboration with Dublin City Council and Intel Corporation, and is focused on the development of a Smart City maturity model.

This paper focuses on the research methodology that is being used for this study, i.e. Action Design Research (Sein et al. 2011). Particularly, we will describe why this recently proposed methodology is suitable for our research, in comparison with Design Science Research (March and Smith, 1995; Hevner et al. 2004) and Action Research (Baburoglu and Ravn, 1992). Furthermore, while we provide an overview of the whole research method in relation to our study, we will focus on the problem formulation stage to systematically investigate the topic.

While engaged in the literature review phase of the research, it arose that the most frequent critique of maturity models is their poor theoretical formulation (Biberoglu and Haddad, 2002). However, most of the models are based on practices and factors that have led to successful results in projects already implemented within certain organizations or industry sectors (Mettler, 2011). In our case, in order to systematically define the content of our maturity assessment model, we aimed at leveraging the awareness of the mechanisms that characterize cities (by involving the critical city's stakeholders), and the technological infrastructure associated with cities (from the company side), with the knowledge arising from extant academic theory. Hence, the second part of this paper explores the factors required to evaluate the environmental and socioeconomic sustainability impact of Information and Communication Technology (ICT) solutions at a city level. A systematic literature review was implemented to develop and propose a smart city definition. Furthermore, a Smart City overview is proposed, containing enabler factors and domains where ICT solutions are expected to be implemented. Finally, Grounded Theory (Yancey et al. 1986) principles are used to structure these domains and to make them mutually exclusive. This process will allow the research team to categorise services that are potentially delivered under the Smart City concept, and so to identify the key city stakeholders (in terms of service providers from both the public and the private sector) that will contribute in designing the content of the Smart City maturity model.

2 Background of problem motivation

The overall goal for this research project is to provide a dynamic assessment model for Smart Cities that can be applied to any city context. A "quadruple-helix" approach (Carayannis et al. 2009) was adopted, where the awareness and the influence of the city authority as well as the technological experience and insights of Intel Corporation, could be combined with rigorous research from the academic field. Moreover, the involvement of representatives of city's service providers and citizens will ensure the presence of the "people component" in our people-private-public partnership collaboration model, which is considered critical in any Smart City project (Schaffers et al. 2012).

The research motivations came from two different sources. On one side, we conducted a systematic literature review to identify the research opportunities within the existing literature base. Here, we found that, despite the definition of many static indexes to assess the "smartness of cities", e.g. (Giffinger et al. 2007; Lee et al. 2012), there is still a lack of dynamic assessment models (Lombardi et al. 2012). The second motivation for this research project came from an organizational-related problem. The Dublin City Council senior management team highlighted the need they have for a comprehensive model in order to assess the current position of the city's Digital Master Plan. According to Dublin Lord Mayor Naoise O'Muiri', the master plan will be modelled with the idea of promoting initiatives to create an *"everywhere digitally connected and sustainable city, from home to*

workplace, from streetscape to public park and from healthcare to education". In the city's managers opinion a solution should be also able to define an improvement strategy in relation to the city's characteristics, priorities, and constraints. Taking the first problem (the one related to the dearth of existing theory), it is clear that an IS-related artifact is needed. As a consequence, a Design Science Research (DSR) method could be used for this research. DSR is defined as a construction-oriented view of IS research in which the main focus is around designing and building innovative artifacts (Hevner et al. 2004), that should be relevant to the solution of an unsolved problem. Moreover, "*the development of the artifact should be achieved from existing and proved theories and knowledge and should be a solution of a defined problem"* (Peffers et al. 2007). On the other hand, if we consider the challenge articulated by the City Management Team, an organizational solution is needed. As a consequence the rationale for the choice of DSR as the proper research methodology becomes weaker. In fact, in DSR the organizational intervention is considered to be secondary (Cole et al. 2005). If we did consider only this side of the research motivation, we would probably choose Action Research (Davison et al. 2004), which can be seen as the combination of theory and researchers intervention to solve immediate organizational problems. However, once the organization-related solution is designed and evaluated, various forms of the organizational context are inscribed into the artifact (Nandhakumar et al. 2005). As a consequence the contribution to existing knowledge might suffer due to the lack of insights for the generalization of the problem and solution instances. Thus, concerning this research project we had to incorporate an "action research component" within a DSR approach. In literature an interesting (and consistent to this study) attempt to combine these two approaches was done in (Ivari and Venable, 2009). The scheme that we considered involves a naturalistic evaluation, as opposed to an artificial one, as our artifact will be much more involving conceptual elements rather than technical ones. Here, the organizational involvement (i.e. the action research component) happens only during the evaluation of the already developed artifact. In our case there are two main differences and inconsistencies. In first place, Dublin City Council (and so the organization), is involved since the very first stage of the research. Secondly, the artifact will be designed and developed in a highly participatory approach with the organization (Dublin City Council) and the practitioners (from Intel). Accordingly, we chose a recently proposed methodology called "Action Design Research" (ADR) which is defined as a research method for generating prescriptive design knowledge through building and evaluating ensemble IT artifacts in an organizational setting (Sein et al. 2011). Its particular contribution is linked to the implementation of design science research to solve an organizational-related problem defined as an instance of a class of problems (Alsleben, 2012). The ADR cycle is based on four main research stages: (1) Problem Formulation, (2) Building Intervention and Evaluation, (3) Reflection and Learning, and (4) Formalization of Learning. The first step of the ADR cycle involves the definition of the problem that is required to be solved. Here, the problem has to be identified, articulated, and scoped. Particularly important at this stage, is to relate the organizational problem to a broader class of problems. Earlier in this paragraph, we have underlined how the city council's need can be seen as an instance of a class of problems that we have identified through our systematic literature review process. Other fundamental inputs for this research came from practitioners (from Intel), researchers (Intel and Dublin City Council) and end-users (Dublin City Council and citizens of Dublin). Thus, the ADR methodology was seen as a particularly appropriate research collaboration model for this Smart Cities project. At the beginning of this research a strong partnership between the stakeholders involved was officially established, and it was followed by initial meetings in which objectives, roles of participants, and priorities were clearly defined. Thus a long-term commitment to the project was achieved. Finally, after a highly participatory preliminary analysis of the project between the parties involved, two initial research questions were formulated: (1) how can Smart Cities be assessed in relation to their current and future ability of delivering services enabled by ICTs? (2) How can insights be given to city's managers to increase and optimize such capability?

The second stage of the ADR methodology is related to the process of building, intervention, and evaluation (BIE) of the artifact (Sein et al. 2011). After discovering initial theoretical contribution

targets, we had to select and customize the BIE cycle. Within the continuum between an IT-dominant-BIE (that is mainly focused on technological design) and an organization-dominant-BIE (this format is related to the decision making processes within the organization), our research is much closer to the second option. This choice was due to the fact that the artifact will be designed with an organization's participants input and ideas. As a consequence, our BIE cycle identifies a highly participatory process with the evaluation phase that can be seen as a concurrent step, rather than a separate stage. The third step of ADR is crucial to ensure the contribution to knowledge of this research project, and it focuses on the reflection and learning process. The presence of researchers from academia is facilitating this process, as their main interest is to keep the process rigorous and systematic. Finally, the last stage proposed in (Sein et al. 2011) emphasizes once again the importance of having a generalized outcome that can be further developed into general solution concepts for a class of field problems. This process is being undertaken in parallel to the on-going BIE stage, which is now under development. A summary of the progress of the research is provided in Figure 1. In particular, within the ADR cycle proposed in (Sein et al. 2011), the stages that have been already implemented are highlighted in red. As mentioned in this section, we achieved the definition of the problem, through inputs from researchers, end-users and practitioners, through a systematic empirical investigation using grounded theory (Yancey et al. 1986), expert interviews, and focus groups workshops, and a systematic review of the literature. Finally we derived two broad research questions that encompass both the need of the city council and the theory-related lack.

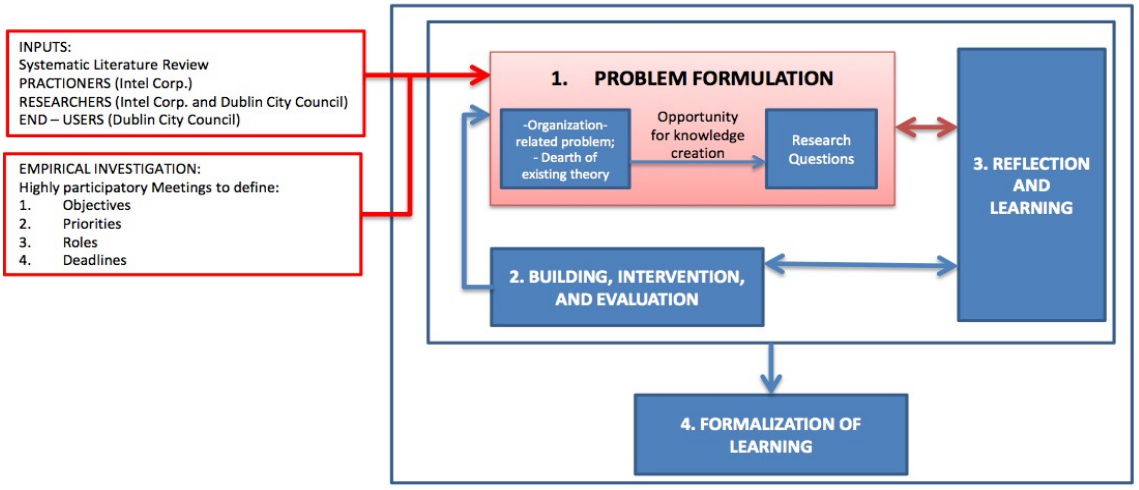

Figure 1. Action Design Research Cycle, adapted from (Sein et al. 2011).

In this section we described the research methodology. We also highlighted how ADR methodological guidance can fit in a highly collaborative environment such as the field of Smart Cities.

3 Systematic literature review

Within the first phase of the ADR methodology we had to investigate the complex domain of Smart Cities. The Smart City concept is still emerging, and the work of defining and categorizing it is in progress (Boulton et al. 2011). In fact, most of the definitions provided come from individual research needs or perspectives (Abdulrahman et al. 2012). As a consequence, a systematic literature review was implemented. This process adhered to Okoli et al's 8 step methodology (Okoli et al. 2010). These steps are: (1) Purpose of the Literature Review, (2) Protocol and Training, (3) Searching for the Literature, (4) Practical Screen, (5) Quality Appraisal, (6) Data Extraction, (7) Synthesis of Studies, and (8) Writing the Review. These steps will be now described and contextualised. The first step of the methodology addresses the fundamental question *"Why do a literature review?"*. In our case, this study was conducted to analyse the stream of research connected to Smart Cities. Furthermore, using a

rigorous approach for analysing the current advances in literature on the topic under consideration (i.e. Smart Cities) is one of the fundamental activities within the problem formulation step of the Action Design Research methodology (Sein et al. 2011).

Within the second stage of the process, the specific steps and procedures to be followed have to be detailed. In this way, three key review questions (RevQ) were defined: what does the term Smart City mean? (RevQ1); which are the homogeneous dimensions that fully encompass all the enabler factors of Smart Cities? (RevQ2); how can a city be decomposed into critical domains in which services delivered under the Smart City concept can consistently fit? (RevQ3).

The approaches that were followed were similar for these three RevQs. Specifically, we used as guidance the Concept Definition Matrix methodology proposed in (Webster et al. 2002). To answer RQev3 we had to define what we meant for Smart City Domain. Hence, we defined it as an area with a certain degree of homogeneity in which services delivered under the Smart City concept can consistently fit. Moreover, each domain must encompass a range of activities that have a meaning within the development of a Smart City strategy, and the ensemble of all the domains must identify exhaustively all the services delivered. This process was externally validated by experts in systematic literature review within the academic field. Concerning the third step of the methodology, the sources of literature that we considered were three; in first place we looked at the most important journals' websites following journal rating charts such as the "AIS Basket of 8"; also open access databases (Google Scholar) and specific subject databases (ACM Digital Library) were included. In total we collected 890 articles. We then applied first exclusion criteria to titles (e.g. language), there were 442 articles left that were ordered and searched, and considered further. Within the practical screen step, we first reduced the total amount of articles by reading the abstracts of all the papers we had previously collected. Then, we carefully read all the papers. In particular, we verified their consistency with the RevQs. As a result we considered 12 contributions for answering RevQ1, 30 for RevQ2, and 42 for RevQ3.

At this stage, a complete list of articles that comprised all of the materials needed to answer our RevQs was available. Therefore, we isolated the information relating to the three relevant objectives for this study. We listed all of the definitions in a table. We then extracted all the dimensions used to conceptualize the Smart City and we followed the same procedure for the Smart City Domains. The output of this step was a complete list of relevant concepts from which we could synthesize our study and derive our conclusions.

With respect to the definitions, we first looked at the syntax of the sentences. While doing so, we defined a common structure characterized by a number of main areas in which all the concepts that arise from these definitions can consistently fit. Examining the texts of the definitions we then classified at a high level of abstraction the components of such phrases, stating that: "*The Smart City is a [Context] that exploits / uses / leverages / develops an [Infrastructure] with-a-certain / implementing an [Approach] supported by [Factors] to enable [processes] to achieve/ improve / enhance / increase [Goals]"*. In other words, every single key concept that is stated in the definitions is related to one of these six main areas, i.e. context, infrastructure, processes, approach, factors, goals. So, after checking its validity, we've decomposed all the definitions into their key words or notions. Hence, with all the words/notions available, we followed the concept matrix method (Webster et al. 2002) in which each key word/notion is related to the author and grouped within the category to which it belongs (see Figure 2). After a preliminary investigation of the definition concept matrix, we could infer that a Smart City could be described as an initiative that exploits technologies to deliver smart information services aiming at better environmental performances, increase or add efficiencies, and improve city's competitiveness or, in other words, develop the so called Smart Economy (Giffinger et al. 2007). A recurring theme refers to the human/social capital as a key enabler of Smart Cities. However, insights about important innovative approaches (Schaffers et al. 2012), and new management and governance principles (Nam et al. 2011) were still lacking in these definitions.

Definitions	Context						Infrastructure							Processes					Approach						Factors			Goals								
References:	Urban area	Mean	Way	Result	Initiative	Urban environment	Physical infrastructure	ICT	Intelligent City	Human capital	Social Capital	Relational Capital	Communication infrastructure	Exploit information	Data collection	e-governance	Generate the knowledge-base	Delivering smart services	Triple-helix	Creative strategy	Knowledge intensive strategy	Government-driven	Participatory governance	Interactive information	Performance metrics	High-tech and creative industries	Stakeholders	Environmental sustainability	React quickly to problems	Make better decisions	Add efficiencies	Improve city's operations	Sustainable economic growth	Social performances	Urban growth	High quality of life
[Kanter]							x							x	x				x						x			x	x	x	x					
[Harrison]	x																														x				
[Castineira]		x							x										x																
[Helal]			x					x																				x					x			
[Naphade]								x							x																	x				
[Lombardi]								x		x	x	x																x								
[Tranos]								x			x					x										x		x					x	x	x	
[Kourtit]				x																x	x							x				x	x	x		
[Leydedorff]								x	x								x	x	x													x	x	x		
[Kuk]					x																	x														
[Caragliu]								x		x	x		x										x													x
[Schuurman]						x																	x	x			x									
Tot.	1	1	1	1	1	1	1	6	2	2	3	1	1	1	2	1	1	1	3	1	1	1	2	1	1	1	1	5	1	1	1	3	3	2	1	1
Tot. per Area	6						16							6					9						3			18								

Figure 2. Definition Concept Matrix.

Then, we went into a greater level of detail aiming at the definition of mutually exclusive and collectively exhaustive areas that fully encompass all the enabling factors of Smart Cities. Initially, it could be concluded that ICTs play a crucial role as enabler of Smart Cities. To explore how the technological infrastructure might look like we describe the development process that has led to its creation. We identified three fundamental milestones in building the technological background for Smart Cities, named the Spatial Intelligence of Cities (Mitchell, 2007): Ambient Intelligence (AI) (Gasson et al. 2007), Digital City (Besselaar, 2005), and the Intelligent City (Komninos, 2002). An AI-oriented perspective of the city would mean leveraging the possibility to collect the data pertaining the city, and so observe the urban system at a micro level. The second step refers to the creation of a ubiquitous computing environment (Greenfield, 2006), to aggregate these data consistently and to structure the knowledge about human life, environment, and social behaviors (Guo et al. 2011). At this step then the Smart City is both "instrumented" and "interconnected" (Dirks, 2009). Finally, in order to reach the "Intelligent City Status", the problem solving capability is added to the process. Here, the digital space becomes a tool that contributes to the capacity of the community to use collective intelligence and engineer new solutions to people's needs (Flew, 2008)(Chen-Ritzo et al. 2009).

Furthermore, developing human resources and social capital are recognized, together with technology, as one of the enabler factors for Smart Cities by many researchers, e.g. (Toppeta, 2010). There are four critical concepts for human factors within Smart Cities, and they are (Nam et al. 2011): Learning City (Plumb et al. 2007), Creative City (Hall, 2000), Human City (Streitz, 2009), and Knowledge City (Dirks, 2009). The central idea here is to develop a highly skilled information workforce, stimulate human's creativity and the development of digital skills that are crucial requirements to overcome the gap identified in (Komninos, 2008), i.e. to turn innovative digital technologies into applications. According to literature, collaboration, participation, engagement, and partnerships are key words related to this field (Giffinger et al. 2007). Hence, we need a collaboration model to actually establish technological and social components as enablers for Smart Cities. To support these approaches, researchers advocate the use of the "triple-helix" model which focuses in particular on relations between university, industry and government at an urban and regional scale (Etzkowitz et al. 2000). However, the potential value of co-creation through citizens, and more generally end-users, involvement is not addressed in this model. As a consequence the collaboration model that has to be set up has to be between local governments, research institutes and universities, citizens and businesses, thus creating a "3P" (Public-Private-People) Partnership. Moreover, up to now, cities' initiatives were dominated by top-down approaches (Schaffers et al. 2012). Consistent with what was

stated about the Public-Private-People Partnership model, the balance between bottom-up and top-down strategies must be strengthened. To achieve these goals managerial interoperability across city's smart services, applications, and organizations is required (Nam et al. 2011). At this point of development, we are in a good position to implement a Smart City strategy. Initially, we can state that the final goal of a Smart City is to provide services (Giffinger et al. 2007) in order to: improve city's inhabitants' quality of life (Hall, 2000), decrease city's carbon footprint (Angoso, 2009), and facilitate a sustainable economic growth (Doobs et al. 2012). Finally we needed to analyze and categorize the city's domains in order to see where these services are actually delivered. The Smart City Domains Blueprint we propose, is made of six general areas. These six domains that we have chosen consistent with the definition provided above, are: Economy and Innovation, Movement and Transport, Culture and Entertainment, Community and Citizenship, Environmental Practices, and Urban Places and Spaces.

As a result of this process, we propose a comprehensive definition for Smart Cities. In particular we define a Smart City as "*an urban area that leverages its technological and social infrastructure implementing people-private-public partnerships supported by innovative governance in terms of policies, leadership and proper ongoing management principles, to enable smart information services, aiming at improving its critical capabilities"*. This definition encompasses all the critical aspects that arose from the literature currently available. Then, as mentioned above, we went into a greater level of detail with the definition of the enabler factors for Smart Cities, and these are: "Technology", "Social Infrastructure", "Governance", "3P Partnerships" (People-Private-People Partnerships), and "Information Services". Finally we decomposed the city into its critical domains, in order to be able to generally understand where these information services are actually delivered.

4 Grounded theory exercise

At this stage we achieved a comprehensive understanding of the Smart City concept, and of its conceptual elements. From the definition we provided, we postulate that, in first approximation, the ultimate goal of a Smart City initiative is to deliver services across the Smart City Domains. At this stage, we needed to systematically define the content of the Smart City Domains, in terms of detailing the services that are potentially delivered, once the enabler factors are properly implemented.

In order to develop a new field of knowledge IS literature recognizes that is necessary to develop theory about pertinent phenomena (Glaser et al. 1967). In our case the relevant component is represented by services that are delivered under the Smart City concept. So, due to the complexity of the "raw data" that had to be analyzed, we needed a method that was both rigorous (to ensure the contribution to existing knowledge of the final outcome), and flexible (in order to be able to study a complex range of data). Among IS researchers, a methodology that is acknowledged to have both these characteristics is Grounded Theory (Birks et al. 2013). It is seen as a powerful tool for rigorous theory development, and it is believed to be grounded in the analysis of actual settings and processes (Urquhart et al. 2009). Thus, to study them, the technique of Affinity Diagrams was adopted. Affinity Diagrams are here understood as a business tool that allows large number of ideas from brainstorming and/or data to be sorted into groups based on their relationships. An approach that allows looking at this concept from a Grounded Theory perspective, is provided by the so called KJ Method (Scupin, 1997). It takes the name from its inventor, the Japanese anthropologist Kawakita Jiro. He defined this method as "*a tool used to organize large amount of qualitative data into logical and linked categories based on recognizable relationships*", and proposed four steps for its implementation: (1) collection of data, (2) creating post-its / notes, (3) putting up the notes, and (4) grouping the notes.

As a first step we had to collect the relevant data. To do this, the research team spent one month collectively building and populating a database of evidence and examples. Individuals within the group were assigned specific domains and given the task of locating and adding representative Smart City services/initiatives implemented in cities around the world and/or designed in theory. In total, we

extracted 164 different instances. For each of them a description, the benefits (where available), and the reference were provided. Hence, one of the members of the focus group started to carefully read each of the initiatives/services. Meanwhile, all the others were responsible for writing their ideas, thoughts, and interpretations about those initiatives/services, highlighting the elementary digital component/capability of each of them. This activity was conducted through small post-its, and each of the members had to make the idea clear in not more than one sentence. All of the post-its were put on whiteboards under the column of the domain of pertinence. The process ("reading", "writing", "putting randomly on the whiteboard") was re-iterated for every domain (see Figure 3a). Once all the post-its were on the whiteboard, we started the grouping stage. First of all we checked the interpretation of the notes, and then we conducted the so called "sniff test", aiming at grouping the notes in relation to their affinity to each other. In order to facilitate the next step, we also labeled in first approximation each of these groups (see pink post-its in Figure 3b). Finally, as suggested by the KJ Method, we created groups of groups, and where possible also a hierarchical diagram was provided (see Figure 3c).

Figure 3. The KJ Method; from the left: Figure 3a, 3b, and 3c.

As a result, we decomposed the Smart City Domains into 28 mutually exclusive sub-domains. Each of them includes a range of Smart City services. The research team is currently working at identifying key stakeholders within these sub-domains to collaboratively shape and design the content of the maturity model across the enabler factors previously introduced.

5 Concluding discussion

In this paper we presented the progress of our research project that aims at the development of a maturity model for Smart Cities. The paper demonstrates the suitability of Action Design Research (Sein et al. 2011) to systematically focus on the complex problem formulation challenge associated with the topic of Smart Cities. We also presented our systematic review of the literature, as part of the first step of this recently proposed methodology. In detail, we showed how a systematic approach to review the existing literature can be used in ADR to focus and provide a problem statement. One of the main challenges of the whole project is to avoid the risk of designing a solution for Dublin City that is not reflected into an original contribution to the existing theory. However, we showed that our grounded theory exercise used as underline concepts the main findings achieved in literature so far, and initiatives that were either implemented in cities all around the world, or designed in theory. Hence, undertaking this process allowed us to relate the Dublin City solution to a generalized outcome consistently with the ADR methodology. In other words, instead of taking the theory and adapt it to the Dublin's urban environment, we leveraged the needs-inputs-ideas-knowledge from DCC to enrich existing knowledge on Smart Cities. So, we made a significant step towards an innovative easy to read format of a Smart City strategy, that will allow the involvement of city's stakeholders in designing a maturity model for smart cities. The next step of the research will be to include service providers from both the public and the private sector within each of the sub-domains identified. This process will contribute to shape the content of the maturity model, and to the overall BIE cycle.

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